Outwitting Shakespeare: Unpacking the Mechanics of Immersive Storytelling with Physiological Measurements

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Completed Research Paper

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Abstract

The core narratives of Shakespeare's storytelling are built around human passions, such as love stories, ambition narratives, and betrayal and revenge plots. Immersive storytelling has been increasingly employed for educational purposes and awareness promotion. Both national agencies and international organizations are utilizing 360-degree videos to present immersive storytelling to garner social attention toward sustainability issues. Despite the prevalence of virtual immersion, there is a lack of understanding regarding how immersive narratives can facilitate knowledge acquisition. Drawing on the narrative transportation literature, we consider the effects of immersive narratives on sustainability knowledge acquisition and investigate the underlying mechanisms of the relationships. We tested our hypotheses in an experiment involving physiological measurements. Overall, this study contributes to IS literature by unraveling the effects of immersive narrative on green learning.

Keywords: narrative transportation, visual engagement, emotional arousal, sustainability knowledge

"And so, from hour to hour we ripe and ripe,

And then from hour to hour we rot and rot;

And thereby hangs a tale."

William Shakespeare, As You Like It, Act 2, Scene 7

Introduction

The core narratives of Shakespeare's storytelling are built around human passions, such as love stories, ambition narratives, and betrayal and revenge plots. Literary scholars generally agree that Shakespeare's stories were constructed by adopting a generalized, relatable narrative template (e.g., young people fall in love but face familial complications), populating the narrative with characters (e.g., Romeo and Juliet), and turning the narrative into a specific story with a time and place. More importantly, the memorability and recognizability of Shakespeare's plays have turned those stories into common knowledge and folklore.

These popular narratives provide individuals with experiential expectations of being in love (i.e., Romeo and Juliet), being jealous, or seeking revenge. Shakespeareans often opine that narratives shape our expectations for how the world works, affect what we perceive about the world, and how we make sense of those perceptions.

Global warming has become one of the most pressing problems for the world population. According to the Intergovernmental Panel on Climate Change, global warming has caused extreme weather events that have displaced more than 13 million people (Pörtner, 2022). Unequivocally, global warming is threatening both the lives and livelihoods of many. For instance, in Bangladesh, increasingly frequent and intense torrential rainfall has displaced close to 700,000 individuals yearly over the last decade (McDonnell, 2019). The increase in global temperature can be attributed to various human activities that generate carbon emissions, such as traveling and consuming brown products.

The increasing popularity of the metaverse presents a unique opportunity to enhance public knowledge about consumption-related carbon emissions and promote sustainability behaviors (Bray and Konsynski, 2007; Peukert et al., 2022). Sustainability interventions have traditionally transpired as policy programs and physical awareness campaigns, while digital interventions are becoming an increasingly popular method. More importantly, the metaverse enables a novel form of storytelling through which individuals are not only passively spectating but can actively interact with immersive narratives (Franceschi et al., 2009; Zhao et al., 2022; Zhou et al., 2012). However, little is known about the effectiveness of immersive narratives in promoting sustainability knowledge acquisition and behaviors.

Information Systems (IS) research has made significant strides toward understanding digital narratives. Prior studies have focused on understanding the effects of different narrative formats, such as texts, graphs, and charts, on decision-making (Choi et al., 2015; Kumar & Benbasat, 2004). The IS literature has also explored information presentation for promoting sustainable practices, such as energy-efficient behaviors and environmentally green choices (Loock et al., 2013). However, our understanding of the effects of digital narratives on sustainable practices is far from conclusive. Some researchers found that digital narratives of electricity consumption could motivate energy-saving behaviors (Kažukauskas et al., 2021), whereas others observed household energy usage uptick after individuals viewed those narratives (Byrne et al., 2018). Thus, our first research question is: what characteristics of immersive narratives are essential to promoting sustainability (RQ1)? Drawing on the narrative transportation literature and past Human-Computer Interactions (HCI) research, we elucidate how plot imaginability and protagonist identifiability are essential characteristics in immersive narratives.

Furthermore, scholars suggest that sustainability knowledge is essential for addressing environmental issues. Early sustainability research has generally focused on individuals' intention to participate in pro-environmental programs. More recent research has begun recognizing pro-environmental behavior as a heterogeneous, multidimensional construct incorporating one-off transactional decisions and sustained continual practices (Green and Brock, 2000). Further muddling understanding, while public discourse is shown to be important to promoting sustainability knowledge and ecological consumptions, others find that the efficacy can be somewhat illusional in that it is largely about generating hype and short-lived attention. Accordingly, our second research question is how do immersive narratives affect sustainability knowledge acquisition and pro-environmental behaviors?

The importance of sustainability promotion has fueled increasing scholarly attention to understand the underlying mechanisms for the impact of immersive narratives on sustainable knowledge and behaviors. Despite the attention, our understanding remains far from conclusive. A key reason is that past research has predominately employed survey questionnaires to measure individuals' experience of psychological transportation. Consequently, instead of directly unraveling individuals' dynamic, momentary changes in transportation psychologies in accordance to the narrative, extant work often focused on examining psychological transportation through retrospective recalls. Thus, the third research question is: What are the specific changes in individuals underlying psychologies during transportation experience? Specifically, this study employs physiological sensors and algorithms to directly quantify individuals' fine-grained psychological changes during their immersive experience.

Overall, this study aims to offer fresh insights into the learning and behavioral outcomes of immersive narratives by integrating the narrative transportation literature and past HCI research. Furthermore, by synthesizing research examining processing fluency, we provide a nuanced understanding of the specific characteristics of immersive experience. The remaining sections of this paper are organized as follows. First, we discuss the related literature and explain the hypotheses. We then describe our methodology and results. The paper concludes with a discussion of limitations and future research directions, theoretical implications, and practical contributions.

Related Literature

Psychological transportation is about the mental state in which an individual's cognitions and emotions are predominately occupied as he or she comprehends a story (Green and Brock, 2000). Using travel as a metaphor, Gerrig (1993) suggests that psychological transportation enables individuals to experience a mental departure from their real-life settings to hypothetical worlds depicted in the story. Indeed, it is not atypical for readers to be thoroughly captivated by a novel, losing track of time, and experiencing subjective detachment from their physical surroundings (Van Laer et al., 2014). While various storytelling techniques have been advanced, plot imaginability and protagonist identifiability are predominately recognized as two narrative characteristics essential for transportation experience. For instance, Green and Brock (2000) examined narrative techniques and categorically emphasized the importance of enhancing readers' imagination and cultivating intimate reader-character connections through vivid, illustrative writing styles. The two narrative characteristics will be discussed in the next two sections.

Plot Imaginability and Interface Mapping

The narrative transportation literature has championed the importance of plot imaginability, which is about the capacity to which a story can stimulate mental imagery of readers (Van Laer et al., 2014). According to Green and Brock (2000), the construction of mental imagery involves multiple cognitive processes, such as identifying the relevant narrative information, comprehending the narrative information, and integrating the information with associated memories. Whereas illogical storylines and incoherent plots are cognitively difficult, if not impossible, for individuals to comprehend, logical and coherent stories are easy to understand and are essential for individuals to be cognitively and emotionally absorbed into the narrative.

The HCI literature has offered that intuitive and simple interaction designs are essential to mitigate challenges in information comprehension. Early studies have advanced an understanding of the psychological effects of information technology usage and offered extensive principles for designing interaction artifacts (Xiao and Benbasat, 2007). Subsequent HCI research has increasingly examined interaction mapping, the degree to which virtual actions performed in the digital environment correspond to actual bodily actions, to facilitate optimal digital content learnability. For instance, Birk and Mandryk (2013) examined the effects of explicit, physical controllers on gaming experience. Although traditional gamepads were familiar to gamers, the limited interaction mapping of physical controllers hindered the immersive experience and hampered gamers' positive feelings.

Extending interaction designs to plot imaginability, this study focuses on two types of interface mapping relevant to immersive storytelling: directional mapping and kinesic mapping. Directional mapping facilitates user interaction in the immersive environment by assimilating physical controller usage actions with the corresponding functional changes in digital content. With directional mapping, the immersive experience can be affected by the behavioral disparity between individuals' physical actions on the physical controller and the corresponding virtual actions. To illustrate, in adjusting one's field of vision in typical shooter video games, players utilize directional buttons on the controller for yawing (e.g., pressing the left button to look left) and pitching (e.g., pressing the back button to look up). Kinesic mapping, by contrast, facilitates user interaction with digital content without a physical controller. Instead, users' bodily movement is used to perform the corresponding virtual actions. Extending the shooter video game example, with kinesic mapping, players use their natural head movement to change their field of vision.

Protagonist Identifiability and Visual Orientation

The narrative transportation literature has also discussed the importance of protagonist identifiability, which is about whether readers can assimilate with the depicted experience of the main character (Van Laer et al., 2014). According to Green and Brock (2000), transported individuals not only imagine themselves taking part in the narrative but also envision themselves as the protagonist going through the story. More importantly, the literature suggests that detailed depictions of the main character are essential for protagonist identifiability (Busselle and Bilandzic, 2008; Qiu and Benbasat, 2009). With vivid details about the protagonist, individuals can better comprehend the story through the main character's orientation, enabling individuals to emplace themselves in the existential experience of the protagonist (Escalas and Stern, 2003). Without detailed descriptions, individuals could struggle to emplace themselves in the role of the main character. This hindered self-emplacement inhibits reader-character assimilation and promotes readers' psychological disengagement from the narrative. Similarly, immersive storytelling can become incredibly engaging when viewers identify with the protagonist. Considering the importance of protagonist identifiability, this study focuses on two visual orientation through which immersive storytelling is commonly conveyed: egocentric orientation and exocentric orientation. Egocentric orientation is a viewing perspective through which immersive storytelling is presented in a first-person orientation (Seinfeld et al., 2021). It emphasizes the central emplacement of individuals in the experiential space that mimics the natural visual orientation through which humans experience the real world (Lim and Reeves, 2009). This real-life reminiscence promotes individuals' assumption of personal, direct virtual environment interaction essential for elevated identification with the character (Gonzalez-Liencres et al., 2020).

By contrast, exocentric orientation enables individuals to experience immersive storytelling in a third-person orientation. Also known as the observer perspective, exocentric orientation is often associated with less vivid and less detailed memory recollection (Sutin and Robins, 2007). First-person orientation incites episodic remembering and self-focused rumination, whereas third-person orientation elevates individuals' emphasis on semantic understanding, lowering their emotional involvement. Indeed, visual orientation research suggests that when an event is pictured from a third-person orientation, individuals typically separate the event from their personal experience and assume psychological distance from the event (Libby and Eibach, 2011). Furthermore, exocentric orientation allows individuals to assume an observer orientation, focusing on the protagonist and attributing the development of the narrative to the character's disposition (Storms, 1973).

Hypothesis Development

We posit that the two modes of control mapping (i.e., directional mapping and kinesic mapping) would have a differential impact on sustainability knowledge, which refers to one's understanding of the social, ethical, and environmental issues related to sustainability (Martínez-Martínez et al., 2023). Directional mapping emphasizes the disparity between real-life control actions and digital functional changes. It amplifies the contrast between individuals' physical presence and virtual emplacement in the digital environment. The pedagogy literature has extensively documented how metacognitive evaluations, which incorporate information about past, present, and future knowledge, can be critical to learning (Dunlosky et al., 2013). To optimize knowledge acquisition, individuals naturally, sometimes implicitly, conclude whether something is learnable, whether to continue or quit learning, as well as whether and when to revisit a particular topic (Dunlosky et al., 2013). More importantly, the literature has consistently underscored the precarity of overconfidence in metacognitive evaluations. When learning is not particularly effortful, students can become emboldened by the ease in knowledge acquisition, motivating them to economize their learning strategies (e.g., reducing the time learning topic, distributing learning duration over multiple time blocks, and terminating learning altogether).

Applied to knowledge acquisition through immersive storytelling, with directional mapping, to acquire and comprehend information in the narrative, individuals must confront the explicit disparity between bodily control actions and virtual functional changes. This disparity presents individuals with desirable difficulties in learning (Bjork and Kroll, 2015), which reduces their overconfidence in acquiring knowledge about sustainability issues. To illustrate, in a 360-degree video, animated annotations that explicate the story can be momentarily presented both inside and outside individuals' immediate field of vision. Consequently, to follow the narrative, individuals would have to orientate their visual field to locate the focal annotation. Directional mapping presents an explicit hand-eye calibration challenge in which individuals must perform constant, dynamic mental alignment between physical actions and virtual changes. On the contrary, with kinesic mapping, individuals are spared from confronting the disparity between physical control and virtual changes. Instead, individuals can utilize their natural head movement to orientate their field of vision to locate focal annotations. Consequently, kinesic mapping will enhance the ease of learning, inflating individuals' confidence in acquiring sustainability knowledge.

Therefore, we propose the following hypothesis:

HYPOTHESIS 1 (H1): Compared with directional mapping, kinesic mapping will lead to worse sustainability knowledge acquisition.

Past cognition research suggests that processing fluency, which fundamentally affects individuals' information comprehension, is predominately determined by the congruence or incongruence between information acquired through multiple sources (Schwarz, 2004). Congruence typically occurs when information acquisition from various channels can be performed without extensive elaboration. In contrast, incongruence occurs when individuals must harmonize information from multiple channels. More importantly, with congruent information acquisition, individuals are likely to experience processing fluency that elevates their confidence about information comprehension and induces a positive attitude. Scholars explain that individuals' overconfidence is often caused by the inherent psychological tendency to associate processing fluency with familiarity and safety in human evolutions (Halberstadt and Rhodes, 2003). Consequently, with processing fluency, individuals will likely adopt abstract information comprehension, emphasizing a holistic understanding. By contrast, with incongruent information acquisitions, processing disfluency is likely experienced, prompting individuals to exercise prudence to critically evaluate the acquired information and focus on the specific details in comprehending information (Winkielman et al., 2012).

In comprehending immersive storytelling, as mentioned earlier, control mapping determines how individuals interact with the virtual environment. In the case of exocentric orientation, individuals visualize immersive storytelling in a third-person orientation. The observer's view enables individuals to maintain psychological displacement from the protagonist. With directional mapping, individuals utilize a physical controller to control their field of vision. More importantly, directional mapping emphasizes the disparity between individuals' actual physicality and their corresponding virtual actions, substantiating the psychological displacement incited by exocentric orientation. Consequently, with processing fluency, individuals will likely fall into the "yolk phenomenon" through which superficial information comprehension is utilized for a holistic, general understanding (Fiske and Taylor, 1991). By contrast, kinesic mapping facilitates user interaction without utilizing physical controllers. Instead, individuals perform functional changes in the virtual environment using their natural bodily movement. Such natural interaction can elevate individuals' psychological emplacement in immersive storytelling, which is incongruent with the displacement experience induced by exocentric orientation, inhibiting processing fluency. In essence, with exocentric orientation, compared to kinesic mapping, directional mapping enhances individuals' experience of processing fluency during immersive storytelling, leading to worse sustainability knowledge acquisition.

On the contrary, in the case of egocentric orientation, individuals view the immersive storytelling in a first-person orientation, which emplaces them in the existential experience of the protagonist. As a result, individuals are likely to expect interaction experience that resembles real-life reminiscence (Schultze and Orlikowski, 2010). Directional mapping emphasizes the disparity between individuals' physical being and virtual representation and is not likely to contribute to congruent information acquisition. By contrast, kinesic mapping facilitates embodied interactions by implicitly integrating natural bodily movement with the corresponding virtual actions. Consequently, through the congruence between natural visual orientation and embodied interactions, individuals will likely experience processing fluency during immersive storytelling, leading to worse sustainability knowledge acquisition. Thus, we predict:

HYPOTHESIS 2A (H2A): In the exocentric orientation condition, compared with directional mapping, kinesic mapping will lead to better sustainability knowledge acquisition.

HYPOTHESIS 2B (H2B): In the egocentric orientation condition, compared with directional mapping, kinesic mapping will lead to worse sustainability knowledge acquisition.

Recent development in narrative transportation argues that individuals' transportation psychologies mediate the effect of plot imaginability and protagonist identifiability on their narrative understanding (Wang and Tang, 2021). Following the narrative transportation literature, we focus on two components of transportation psychologies, i.e., visual engagement and emotional arousal. Visual engagement represents individuals' cognitive deliberation during their comprehension of the storyline. According to Green and Brock (2000), visual engagement must be maintained for narrative transportation. Simply put, only when the narrative visually engages individuals can they focus on the story and become psychologically transported. More importantly, visual engagement has been extensively employed to examine individuals' cognitive deliberation (Frischen et al., 2007). Past sustainability research has demonstrated the impact of cognitive deliberation on sustainability learning. For instance, in a study examining food sustainability labels, Van Loo et al. (2021) found that individuals' visual engagement with specific attributes of sustainability product labels consistently influenced their valuations of such attributes.

Emerging evidence suggests that the effects of narratives on individuals' learning can be differentially mediated by visual engagement and emotional arousal (Bezdek and Gerrig, 2017). Knowledge acquisition involves multiple information foraging activities that require visual engagement, such as identification of information value, information filtering, as well as information comprehension and internalization (Mccart et al., 2013). Contemporary research examining virtual reality begins to reveal the importance of visual engagement for learning in the immersive environment (Biocca et al., 2007; Steffen et al., 2019). Whereas traditional information foraging research largely focuses on digital content navigation on a two-dimensional structure (e.g., a webpage), knowledge acquisition in immersive narratives necessities individuals to engage in spatial wayfinding in a three-dimensional virtual environment (Jiang and Benbasat, 2004; Nah et al., 2011).

Visual engagement is essential for knowledge acquisition, but emotional arousal may hinder learning. Emotional arousal changes individuals' affective states and drives impulsivity by overriding, if not depleting, individuals' cognitive resources for logical, analytical thinking (Salimpoor et al., 2009). Therefore, we propose the follows:

HYPOTHESIS 3 (H3): The effects of control mapping and visual orientation on sustainability knowledge acquisition are mediated by visual engagement, but not emotional arousal.

Research Method

Figure 1. 360-degree Panorama View

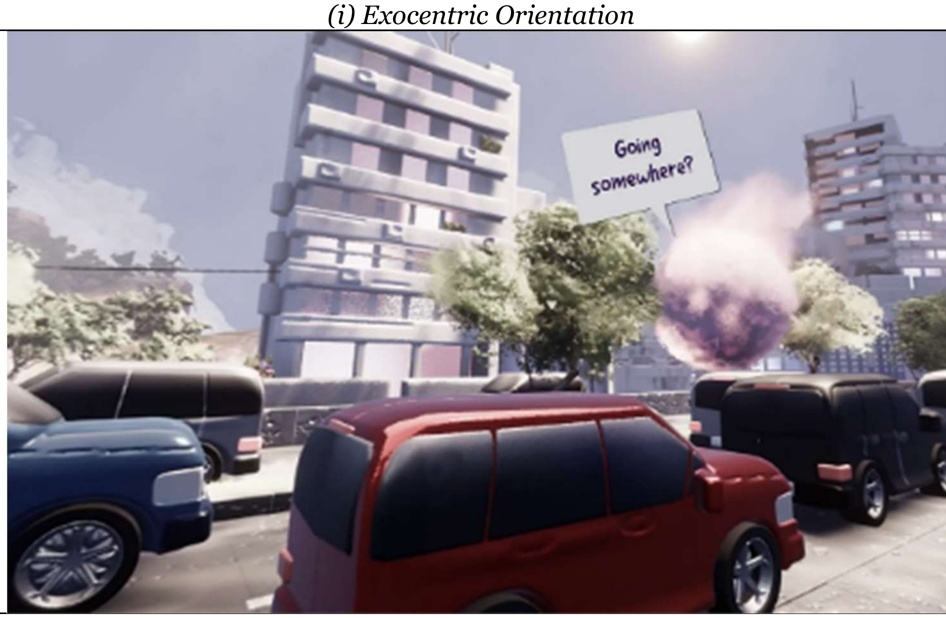
Notes: The rectangular boxes denote a subject's specific field of vision. A, the initial field of vision (FOV), B, FOV after yawing right, C, FOV after yawing left, D, FOV after pitching up, E, FOV after pitching down.

A laboratory experiment with a 2 (control mapping, directional mapping versus kinesic mapping) × 2 (visual orientation, exocentric orientation versus egocentric orientation) between-subjects factorial design was conducted to test the hypotheses. Control mapping in the experiment was manipulated by different control modes. In the directional mapping condition, subjects changed their field of view (i.e., what one could see) using a small joystick on a controller (i.e., the left stick on the Xbox controller). Pushing the joystick to the right (left) performed a right (left) yaw, shifting one's visual field toward the right (left).

Pushing the joystick forward (back) made one look down (up). In the kinesic mapping condition, subjects changed their field of view using a virtual reality headset with rotational tracking that captured head movement, supporting natural viewing directions (i.e., yawing and pitching using corresponding head movement) (Figure 1).

Visual orientation was manipulated by varying subjects' points of view of the immersive storytelling. With an exocentric orientation, subjects viewed the immersive storytelling in a third-person perspective through which subjects assumed an observer's view overlooking the main character in the virtual world. With an egocentric orientation, subjects viewed the immersive storytelling in a first-person perspective through which subjects assumed the main character's view of the virtual world (Figure 2).

(i) Exocentric Orientation

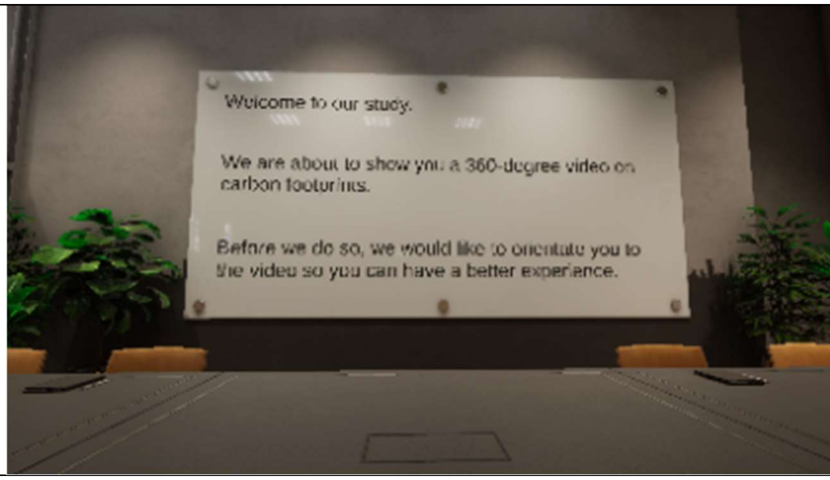


(ii) Egocentric Orientation

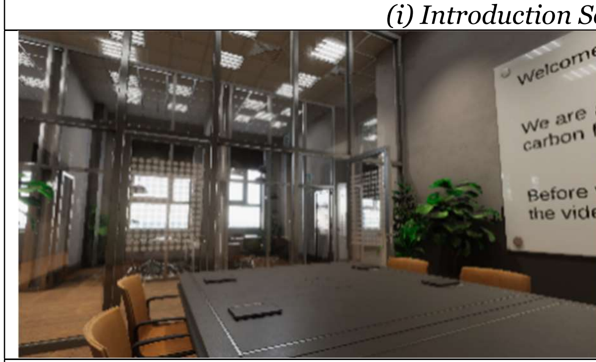
Figure 2. Two Conditions of Visual Orientation

Note: In addition to the above exocentric orientation (i.e., male avatar), subjects in the exocentric orientation condition were randomly presented with the female avatar.

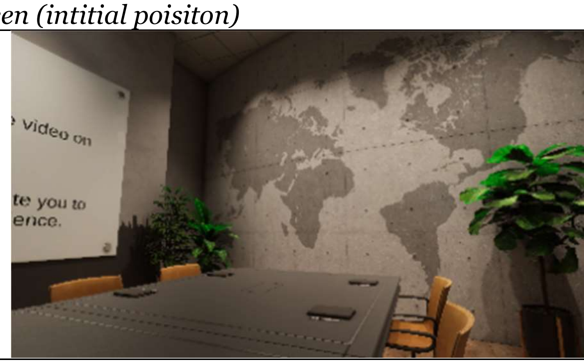
Two hundred and five subjects took part in the main experiment. One week before the experiment, they were asked to provide demographic information, computer gaming experience, and virtual reality usage experience and respond to questions regarding environmental concerns (Perron et al., 2006; Weigel and Weigel, 1978). Subjects were randomly assigned to one of the four experimental conditions. Upon arriving at the research laboratory, subjects were informed that they would be evaluating immersive content design using virtual reality headgear. They were seated at a desk in a temperature and humidity-controlled room and put on the galvanic skin responses (GSR) sensors. The GSR sensors were attached to the subject's hand, the second phalanx of the index and middle fingers. Subjects were instructed to complete a filler task (i.e., ten simple arithmetic problems) to accommodate them with the sensor. Afterward, they remained seated and relaxed for three minutes.



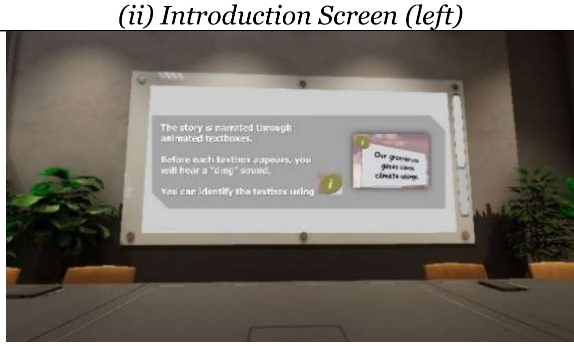
(i) Introduction Screen (intitial poisiton)



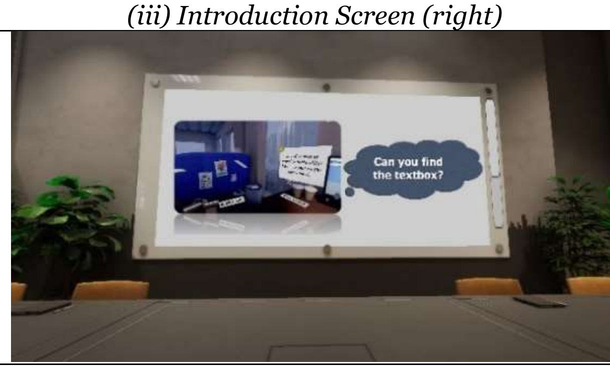
(ii) Introduction Screen (left)



(iii) Introduction Screen (right)



(iv) Animated Textbox Explanations



(v) Animated Textbox Explanations

Figure 3. Familiarization Video

Subjects put on the virtual reality headgear with eye-tracking capability and completed a calibration with the eye-tracking sensors. Subjects then put on the virtual reality headgear with eye-tracking capability and completed a calibration with the eye-tracking sensors. Subjects subsequently viewed two 360-degree videos. The first video was a familiarization video through which subjects got accommodated with the control and viewing of the immersive environment (Figure 3). Additionally, the familiarization video informed subjects about the various visual and audio elements of the immersive content. For example, subjects were told that our storytelling in the 360-degree video would be performed through annotations, which were presented sequentially in standard textboxes for a short duration (i.e., the textbox was typically removed after 5 to 10 seconds). More importantly, subjects were made aware of a distinct audio precursor (i.e., a sharp "ding" sound) that signaled the imminent presentation of annotations. They were also shown that certain annotations could be displayed beyond their immediate field of view, requiring them to change their field of view to locate the annotations. Subjects were free to ask questions if they were uncertain about the familiarization video.

Afterward, subjects were presented with the main 360-degree video, which consisted of five acts with nine scenes for 4 minutes and 33 seconds. The first act was the introduction, providing subjects with an overview of the story. The second act, consisting of three scenes, illustrated the carbon footprint of typical consumptions, namely the breakfast scene (i.e., the typical carbon footprint in producing a breakfast), the daily commute scene (i.e., carbon emission generated through fossil fuel-powered transports), and the office scene (i.e., carbon emissions associated with printing and parcel deliveries). The third act explained to subjects the future environmental impact when typical consumptions were maintained. The fourth act consisting of three scenes, illustrated the green alternates in the breakfast, daily commute, and office scenes. Lastly, the fifth act gave subjects a conclusion, encouraging them to make sustainable, environmental consumption decisions and choices. Subjects were asked to attempt a quiz that assessed their sustainability knowledge.

Data Analysis and Results

The manipulation check for control interface was performed by asking subjects three true/false questions on whether subjects utilized head movement to change their field of vision in the immersive narrative. All subjects in the directional control condition answered "false" to the three questions, and all those in the kinesic control condition answered "true," suggesting that the manipulation of control interface was successful. The manipulation check for visual perspective was conducted by asking subjects three true/false questions on whether the immersive narrative was viewed in a first-person or third-person perspective. Subjects answered the questions correctly, supporting successful manipulation of visual perspective.

Sustainability knowledge acquisition was operationalized using a quiz to assess subjects' environmental knowledge acquired through the immersive narrative. The quiz consisted of six multiple-choice questions and two open-ended questions.

Galvanic skin response (GSR) is an objective, valid, and reliable measure of emotional arousal (Mauss and Robinson, 2009; Reisenzein, 1994). Accordingly, we collected subjects' GSR data to operationalize emotional arousal. We utilized the algorithm proposed by Benedek and Kaernbacj (2010) to filter, extract, and smooth GSR data.

We utilized eye-tracking to facilitate objective measures of subjects' visual engagement. Following the eye-tracking literature, we defined areas of interest to categorize fixation count and dwell time in specific regions (Blascheck et al., 2017). Since the story of our 360-degree video was told through annotations in animated textboxes, to capture subjects' visual engagement following the annotations, we created a distinct area of interest (AOI) on each animated textbox, resulting in a total of 35 AOIs for the entire video.

Test of Direct Effect Hypotheses

ANOVA with sustainability knowledge acquisition as the dependent variable revealed the significant effect of control mapping ($F(1,101) = 14.81$, $p < 0.01$) (Table 1). Therefore, H1 is supported.

Since the interaction effect on sustainability knowledge acquisition was significant ($F(1,101) = 39.07$, $p < 0.01$), we further conducted the simple main effect analysis. Results suggested that the effect of control mapping was moderated by visual orientation. Simple main effect analysis reveals that (1) kinesic mapping was associated with significantly worse sustainability knowledge acquisition than directional mapping under the egocentric orientation condition ($F(1,45) = 73.04$, $p < 0.01$), and (2) kinesic mapping and directional mapping were not different from each other in affecting sustainability knowledge acquisition with exocentric orientation ($F(1,56) = 2.52$, $p = 0.12$) (see Table 1 and 2, Figure 4). Therefore, H2A and H2B are supported.

Source	Type III SS	df	Mean Square	F	Sig.
Intercept	10411.73	1	10411.73	2940.05	0.00
CM	52.44	1	52.44	14.81	0.00
VO	0.31	1	0.31	0.09	0.77
CM×VO	138.36	1	138.36	39.07	0.00
Error	357.68	101	3.54		
Total	10956.00	105			
VO = Exocentric					
CM	11.66	1	11.66	2.52	0.12
Error	258.62	56	4.62		
Total	6272.00	58			
VO = Egocentric					
CM	160.78	1	160.78	73.04	0.00
Error	99.06	45	2.20		
Total	4684.00	47			

Table 1. ANOVA Results and Analysis of Simple Mean Effects

Note. Dependent variable, sustainability knowledge acquisition; CM, control mapping; VO, visual orientation.

	Exo	**Ego**	**Mean**
DM	9.72	11.95	10.84
KM	10.62	8.18	9.40
Mean	10.17	10.07	

Table 2. Mean Values of Sustainability Knowledge Acquisition

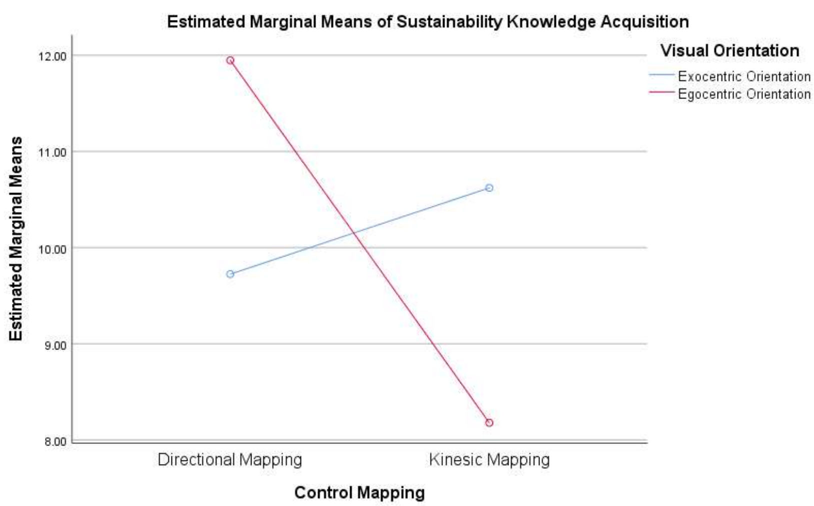


Figure 4. Mean Plot of Sustainability Knowledge Acquisition

Test of Mediated Effect Hypotheses

Past IS research employing laboratory experiments has primarily adopted a cross-sectional approach for data analyses. A careful review of the narrative transportation literature suggests that such an approach might not be adequate to fully reveal the intertwined relationships between individuals' dynamic psychological experiences and specific events in storytelling. For instance, in immersive storytelling, subjects were presented with a 360-degree video (5 acts, nine scenes) comprising 35 annotations in animated text boxes. Furthermore, whereas some scenes depict awful, undesirable environmental damages of consumption, others emphasize pleasant, attractive ecological consequences. Considering the potential impact of annotations on individuals' psychologies, we performed analyses on subjects' emotional arousal and visual engagement as they comprehended the animated text boxes. Specifically, we constructed panel data (i.e., at the annotation level) on subjects' emotional arousal and visual engagement as they were presented with each of the 35 animated text boxes.

More importantly, to further dissect individuals' specific psychological changes, we considered advanced eye-tracking metrics, namely time to first fixation. Time to first fixation (TFF) subsumes the time taken for a subject to fixate on an animated text box. Whereas a short time to first fixation implies individuals' high attentiveness to the animated text box, a long time to first fixation suggests delays in individuals' focus on the animated text box. If no fixation occurred, following the eye-tracking literature (Myers et al. 2020), we used the maximum exposure time of the animated text box as the corresponding time to the first fixation.

Based on the 35 animated text boxes, we constructed each subject's corresponding emotional arousal data. The physiological literature suggests that GSR signal triggered by a specific event (e.g., visual stimulus) might not happen instantaneously but with an unavoidable delay or latency after the event occurred. While the latency varies within and between individuals, a common consensus is to focus on the GSR data in a latency window of about 5 seconds after the event onset. Accordingly, specific to a subject's first fixation on an animated textbox, we constructed event-related GSR amplitude (ER-GSR), which refers to the amplitude of GSR signals recorded 5 seconds after the first fixation on an animated text box (see Figure 5 for an illustration).

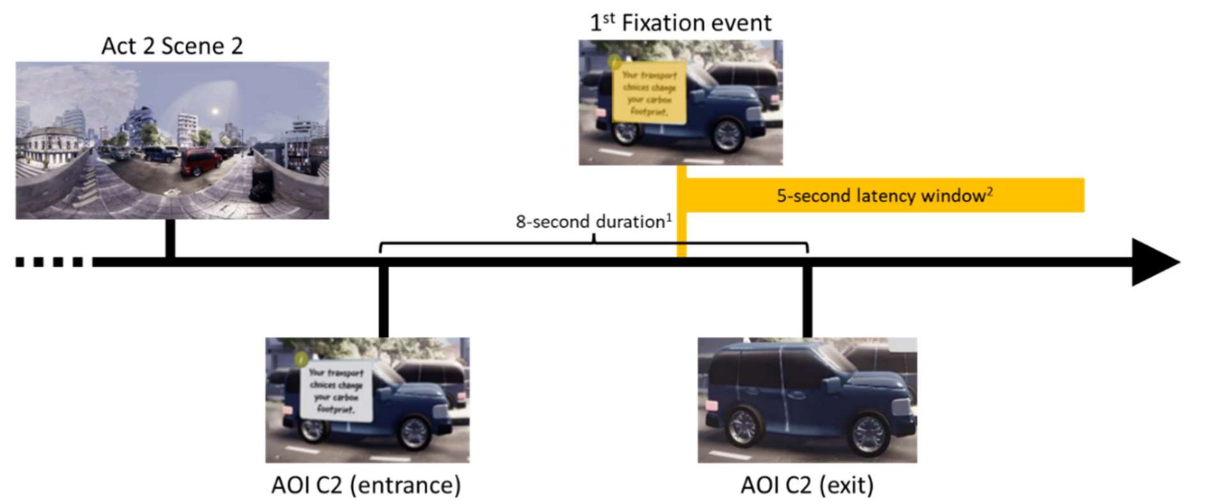


Figure 5. Event Onset GSR Latency Window

Notes: [1] AOI-specific durations. [2] a standard 5-second latency window to compute event onset GSR

To account for the clustered data structure of the mediating variables, we constructed multiple linear mixed-effects models (LMMs) with individual random effects on emotional arousal and visual engagement. Table 3 shows that both directional mapping with exocentric orientation (CM=0 & VO=0) and kinesic mapping with egocentric orientation (CM=1 & VO=1) lead to shorter TFF and stronger event-related GSR amplitude, compared with directional mapping with egocentric orientation (CM=0 & VO=1) and kinesic mapping with exocentric orientation (CM=1 & VO=0).

DV = Time to First Fixation (TFF)						
	OLS			LMM[1]		
Predictors	*Est*	*CI*	t	*Est*	*CI*	t
(Intercept)	154.22***	62.21, 87.26	46.75	64.53***	56.34, 86.63	7.86
CM	25.23***	18.62, 31.53	17.53	34.35***	26.65, 37.53	34.21
VO	0.24	-5.01, 1.24	0.61	0.42	-0.33, 1.21	0.59
CM×VO	-23.46***	-45.52, -53.26	-19.23	-35.34***	-53.27, -64.42	-57.21
χ^2					8723.00***	
DV = Event-Related GSR Amplitude (ER-GSR)						
	OLS			LMM[1]		
Predictors	*Est*	*CI*	t	*Est*	*CI*	t
(Intercept)	2.52***	2.49, 2.64	212.88	2.53***	2.23, 2.64	118.23
CM	-1.05***	-1.50, -1.03	-62.32	-1.07***	-1.10, -1.05	-64.21
VO	-1.05***	-1.21, -1.03	-60.56	-1.07***	-1.10, -1.02	-64.26
CM×VO	1.82***	1.58, -1.28	45.55	1.04***	-0.99, 1.08	81.02
χ^2					244.21***	

Table 3. Results on TFF, RC, and ER-GSR

Note. [1] *denotes the inclusion of individual random effects.*

Building on our findings on the effects of the independent variables on time to first fixation (TFF) and ER-GSR amplitude, we utilized Preacher and Hayes (2004)'s procedure to examine the potential mediating roles of annotation level variables, namely TFF and ER-GSR. To conduct the mediation analyses, based on the annotation level variables, we constructed the corresponding mediating variables at the individual level (i.e., the summation of a subject's scores in TFF and ER-GSR, respectively).

Results in Table 4 reveal that TFF significantly mediates the influence of the independent variables on sustainability knowledge acquisition. Additionally, the mediating effect of ER-GSR on the relationships between the independent variables and sustainability knowledge acquisition is not significant. Therefore, H3 is supported.

The indirect effect of Control Mapping at Conditions of Visual Orientation on Sustainability Knowledge Acquisition via Time to First Fixation					
CM	VO	B	BootSE	LL	UL
= KM	= Exo	1.93	0.21	1.45	2.22
= DM	= Ego	0.05	0.05	-0.01	0.12
= KM	= Ego	-0.51	0.10	-0.42	-0.03
The indirect effect of Control Interface Mapping at conditions of Visual Perspective Orientation on Sustainability Knowledge Acquisition via ER-GSR					
CM	VO	β	BootSE	LL	UL
= KM	= Exo	-0.01	0.40	-0.90	1.01
= DM	= Ego	-0.03	2.01	-3.04	2.34
= KM	= Ego	-0.01	0.49	-1.00	1.01

Table 4. Results of Mediation Tests

Discussion of Results

The results supported all the hypotheses. We proposed that kinesic mapping led to worse sustainability knowledge acquisition than directional mapping. Our results suggested subjects in the kinesic mapping condition achieved worse quiz scores. Also, we expected visual orientation to moderate the effects of control mapping on sustainability knowledge acquisition. As expected, we found that kinesic mapping led to better sustainability knowledge acquisition with exocentric orientation compared with directional mapping, while directional mapping led to better sustainability knowledge acquisition with egocentric orientation compared with kinesic mapping. Consistent with our expectation, visual engagement mediated the effects of control mapping and visual orientation on sustainability knowledge acquisition but not emotional arousal.

Research Implications

First, we contribute to the IS literature by extending the scope of narrative transportation to an emerging domain in which storytelling conveys collective, distal consequences through an experiential perspective. Following early studies on narrative transportation, virtual reality researchers have recommended various design principles to advance storytelling through immersive storytelling. Drawing from this body of knowledge, some behavioral studies have examined designs of persuasive storytelling (Krause and Rucker, 2020) to motivate individuals to modify existing behaviors. However, these studies focus on behavioral changes and rarely examine individuals' understanding of storytelling. Individuals' responsibilities to future environmental problems and the instrumentality of their behavioral changes can be somewhat inapparent in sustainability issues. Consequently, an extant understanding of immersive storytelling techniques may not be adequate for designing persuasive immersive storytelling to promote sustainability knowledge. To our best understanding, this study is among the first to extend the transportation narrative literature to sustainability contexts by elucidating the effects of experiential, immersive storytelling on individuals' sustainability understanding.

Second, we enrich the HCI literature for virtual reality designs by examining two critical characteristics of immersive storytelling: control mapping and visual orientation. Extant HCI works have broadly discussed user interface designs, physical and virtual controllers, and visual orientations. While the literature has substantially advanced design techniques, extant works have yet to explain how specific immersive narrative features can facilitate knowledge acquisition. To this end, our study systematically investigates the effects of control mapping and visual orientation on sustainability knowledge acquisition. In particular, we find that directional mapping is particularly useful in overcoming overconfidence in acquiring knowledge about sustainability issues, contributing to better learning outcome. Our findings can serve as a basis for future studies in complex immersive storytelling, especially when considering persuasive content.

The other immersive narrative feature that we have examined is visual orientation. Storytelling experts have increasingly advocated the importance of utilizing compelling storytelling perspective to facilitate ease of comprehension. Despite the robust recognition, there is a paucity of theory-driven research examining the differential effects of various storytelling orientation on individuals' fluency in comprehending stories. Our theorization of visual orientation offers conceptual explanations for the fundamentally different processing fluency that can be facilitated by exocentric orientation and egocentric orientation, respectively. Our experiment robustly shows that exocentric orientation prompts individuals' displacement from the virtual character, whereas egocentric orientation elicits individuals' emplacement in the role of the virtual character. Such findings contribute to the HCI literature by demonstrating how visual orientation activates psychological emplacement (or displacement) in comprehending immersive storytelling.

Third, we advance the understanding of multi-modality information comprehension in immersive storytelling. Extent HCI studies often focus on the main effects of either control mapping or visual orientation. However, with immersive storytelling, these features are increasingly employed in unison. Drawing on the processing fluency literature, we offer that exocentric orientation would drive individuals to assume an abstract information comprehension strategy, emphasizing holistic, general understanding. In contrast, egocentric orientation would prompt individuals to adopt a concrete information comprehension strategy with an emphasis on acquiring low-level, specific knowledge. In the former, individuals would be motivated to maintain processing fluency by keeping a psychological distance from the immersive storytelling. Consequently, when individuals interact with the virtual environment through directional mapping, they can maintain the disparity between their actual physicality and the corresponding virtual actions. In the latter, individuals would be motivated to emplace themselves in the existential experience of the virtual character. As a result, when virtual interaction is facilitated through kinesic mapping, individuals can maintain a congruence between natural visual orientation and embodied interactions. We are among the first to formally employ the information processing perspective to theorize the joint effects of control mapping and visual orientation.

Lastly, we identify the mediating mechanisms that formally illustrate individuals' transportation psychologies in viewing immersive storytelling. we argue that visual engagement is the critical underlying mechanism explaining the effects of immersive storytelling on individuals' knowledge acquisition. Our discovery reveals that visual engagement can be a prerequisite for determining greening understanding.

Practical Implications

This study makes significant contributions to practice. Our study reveals a powerful way to promote sustainability knowledge through immersive storytelling. Specifically, we find that directional mapping helps individuals obtain concrete and systematic thinking when interacting with immersive storytelling. Hence, we recommend that virtual reality designers consider incorporating directional mapping in designing persuasive digital storytelling. Our findings on promoting environmental learning are extensible beyond the sustainability settings into persuasive contexts such as healthy lifestyles and prosocial practices.

We also reveal the interaction effects between control mapping and visual orientation on sustainability knowledge acquisition. The disparity between egocentric orientation and directional mapping helps individuals avoid the "yolk phenomenon". Similarly, the disfluency induced through the incongruence between exocentric orientation and kinesic mapping promotes concrete, specific information comprehension. Our findings underline the unexpected impact of processing fluency on learning in immersive storytelling. To this end, we suggest that designers consider incorporating visual and narrative elements to manage fluency disruption in developing educational storytelling.

Limitations and Future Directions

There are some limitations that readers should consider in interpreting our findings. First, this study examines individuals' sustainability knowledge after viewing immersive storytelling depicting the dos and don'ts in typical daily consumption. Our results might not be generalized to highly complex and technical sustainability-related decisions and understanding. For example, some green choices (e.g., whether a company should adopt an alternative production procedure) might require individuals to evaluate the utilitarian aspects of options (e.g., comparing the costs between different manufacturing techniques). In such scenarios, the experiential elements of immersive storytelling might not be entirely relevant.

Second, our contributions may also be limited by the 360-degree video. This study utilized an immersive educational video to promote public awareness of consumption-related carbon emissions. While the video follows a typical storytelling structure (i.e., discussing the present issues before presenting some possible solutions), the story can be told using other storytelling techniques (e.g., reversing the issues-solutions sequence). We recommend that future studies consider other storytelling structures and techniques for immersive storytelling.

This study focuses on understanding individuals' sustainability knowledge acquisition immediately after viewing the immersive storytelling. While our findings show that immersive storytelling can powerfully shape these outcomes, our observed effects will likely diminish over time. Relatedly, recent research examining virtual reality has demonstrated the potential of interactive storytelling (i.e., synchronous user-driven storyline) and turn-based storytelling (i.e., asynchronous user-driven storyline). We recommend that future studies consider other storytelling characteristics and conduct field experiments where immersive storytelling can be provided to promote sustainability knowledge. We also suggest future studies to consider expanding our scope to encompass other storytelling characteristics for prompting sustainability knowledge.

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